

Title : Power supply apparatus**Description**Field of the invention

5 This invention relates to power supply apparatus for supplying a direct voltage to a load and comprising a rechargeable battery and a voltage generator for recharging the battery and supplying power to the load,.

Background of the invention

10 Rechargeable batteries are used in many circumstances to power user devices, especially radio communication apparatus such as portable telephones, for example. A charger comprising a voltage generator is provided to recharge the battery. The charger may take the form of an AC/DC converter or a DC/DC transformer, for example.

15 The charger is often connectable to the user device with the battery connected so that not only can the battery be charged but the device can be used while the battery is charging. A problem arises however if the battery is completely discharged since, when the charger is connected and starts to charge the battery, the supply voltage appearing at the user device is too low for the user device to function until the battery has charged partially and remains too low for an
20 inconveniently long time. This can be particularly troublesome in the case of a portable telephone, for example, if the delay is of the order of minutes when the user desires to make an emergency call.

 It is possible to provide control circuits which control the voltage and current supplied by the voltage generator and provide a parallel path for charging the
25 battery. However these control circuits have involved a substantial additional cost.

 It is desirable to provide a power supply with control circuits enabling the voltage generator to power the user device even in the presence of a completely discharged battery with a smaller, or no additional cost compared to voltage supplies without such a 'dead battery capability'.

Summary of the invention

The present invention provides a power supply apparatus and portable radio communication apparatus as described in the accompanying claims.

Brief description of the drawings

5 **Error! Reference source not found.** is a schematic diagram of a known power supply apparatus in a portable radio telephone,

Error! Reference source not found. is a schematic diagram of a power supply apparatus in a portable radio telephone, in accordance with one embodiment of the invention, given by way of example,

10 **Error! Reference source not found.** is a table showing graphic representations of control elements in the apparatus of **Error! Reference source not found.** in different functional states, and

Error! Reference source not found. is a table showing the functional states of control elements in the apparatus of **Error! Reference source not found.** in different operational conditions of the apparatus, using the graphic representations of **Error! Reference source not found.**.

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Detailed description of the preferred embodiments

Figure 1 shows a portable radio communication apparatus, in this example a portable radio telephone 1. The portable telephone 1 comprises a communication
20 module including active signal processing, memory and audio circuits forming a load 2 energised by a power supply applying a voltage to a terminal 3 of the load. The power supply includes a rechargeable battery 4 connected to a terminal 5 for supplying power to the load 2 during normal usage of the telephone 1.

The power supply also comprises a charger 6 in the form of a voltage
25 generator that may be connected to a terminal 7 of the telephone 1 to charge the battery 4 and, if necessary, to power the load 2. Typically, the charger is an AC/DC converter but it may alternatively be a DC/DC transformer, for example. The charger 6 supplies power to the battery 4 along a charging path 8 to a connection point 9 connected with the battery terminal 5 through a current sensing
30 resistor 10. The connection point 9 is connected to the load terminal 3 through a

blocking control element 11 whose function is described below. The control element and other control elements described below are operated under the control of microcontroller unit 12.

5 The charger terminal 7 is connected to the charging path 8 in series through a clamp control element 13 to a connection point 14. The charging path 8 then includes in series a charge control element 15, a reverse current blocking control element 16 and a current sense resistor 17.

10 The control elements are discrete field-effect transistors ('FETs') and, in this example are unidirectional FETs. As illustrated by the symbol of a diode, the FETs allow a parasitic current to flow even when subjected to a reverse voltage.

In operation, with the charger 6 disconnected, the battery 4 supplies power through the current sensing resistor 10 and the blocking control element 11 to the terminal 3 and the load 2, the blocking control element 11 being biased to a conducting state by the MCU 12.

15 When the charger 6 is connected, in normal charging conditions, the charger supplies power through the charging path 8 to the connection point 9, the charging current being controlled by the MCU through the charge control element 15 in dependence on the voltages and currents sensed.

20 If the charger 6 is connected to the terminal 7 before being energised and power is then applied, the voltage at the terminal 7 can be excessive. This condition is monitored by the MCU 12 and regulated through the clamp control element 13.

25 If the charger is unplugged (de-energised) while still connected to the terminal 7 with the battery 4 charged, the MCU 12 switches the reverse current blocking control element 16 to a non-conductive state to prevent the flow of reverse current into the charger 6.

30 If the battery 4 is at a low state of charge, the charger 6 is able to supply sufficient power to operate the active circuits of the load 2. However, if the state of charge of the battery 4 is too low, the charger cannot raise the voltage at the terminal 3 to a sufficient level to operate the active circuits of the load 2 until the battery 4 has charged at least partially; this can take several minutes, during which

time the telephone is unusable. Accordingly, a supply path 18 is provided in parallel with the charging path 8 to enable the charger 6 to supply power directly to the terminal 3 and the load 2. A blocking control element 19 is connected in series in the parallel path 18 and the MCU 12 normally maintains the blocking control element 19 non-conducting and the blocking control element 11 conducting so that the power supply and charging currents from the charger 6 pass along the path 8 and are controlled by the control elements 15 to 17. However, when the MCU 12 senses that the battery voltage is too low, it makes the blocking control element 19 conducting and the blocking control element 11 non-conducting, so that the charger 6 supplies power to the terminal 3 and the load 2 along the path 18 and the battery 4 is disconnected from the terminal 3 so as not to drag down the voltage at the terminal while the battery is still discharged.

The voltage supply apparatus shown in Figure 1 fulfils the basic function of enabling the charger 6 to power the load 2 with a dead battery 4 or with the battery 4 removed but it requires 5 discrete control components, which adds cost to the telephone, and in addition, these components occupy space on the circuit board, which further increases the cost of ensuring dead battery operation.

The voltage supply apparatus of the embodiment of the present invention is able to provide dead or missing battery operation with fewer components, comparable with the number of components in a telephone incapable of dead battery operation, so that the dead or missing battery operation feature involves substantially no on-cost.

In Figure 2, elements that are similar to those of Figure 1 bear similar reference numbers. The charger terminal 7 is connected to the connection point 9 through a charging path 8. The load terminal 3 is connected directly to the connection point 9. The MCU 12 controls the charging current in, and the voltage applied to the path 8 through a clamp and charge control element 20 in series in the path 8, reverse current being controlled by the blocking element 16. A blocking and charge control element 21 is connected in series with the current sense resistor 10 between the battery terminal 5 and the connection point 9.

The charging clamp and charge control element 20 and the battery clamp and charge control element 21 are controlled by the MCU 12 to present a high

impedance, non-conductive state or a low impedance, conductive state or a controlled impedance state in which their impedance is controlled as a function of the sensed current and/or voltage variables so as to control the magnitude of the currents they supply.

5 In operation, with the charger 6 disconnected, the battery 4 supplies power through the blocking control element 21 and the current sensing resistor 10 to the terminal 3 and the load 2, the blocking control element 21 being biased to a conducting state by the MCU 12.

10 When the charger 6 is connected, in normal charging conditions, the charger supplies power through the charging path 8 to the connection point 9, the charging current being controlled by the MCU through the charge control elements 20 and 21 in dependence on the voltages and currents sensed. The proportion of current supplied to the battery 4 instead of the load 2 is controlled by the charge control element 21.

15 If the charger 6 is connected to the terminal 7 before being energised and power is then applied, the voltage at the terminal 7 is regulated by the MCU 12 through the clamp control element 20.

20 If the charger is unplugged (de-energised) while still connected to the terminal 7 with the battery 4 charged, the MCU 12 switches the reverse current blocking control element 16 to a non-conductive state to prevent the flow of reverse current into the charger 6.

25 If the battery 4 is at a low state of charge, the charger 6 is able to supply sufficient power to operate the active circuits of the load 2. However, if the state of charge of the battery 4 is too low, the blocking and charge control element 21 connected in series between the battery terminal 5 and the connection point 9 is rendered non-conducting by the MCU 12, so that the charger 6 supplies power to the terminal 3 and the load 2 with the battery 4 disconnected from the connection point 9 so as not to drag down the voltage at the terminal if the battery is totally discharged; the battery can charge over the path 8 even while the charger 6
30 supplies power to the load 2 if the charger power supply is sufficient, the MCU 12 putting the blocking and charge control element 21 in an intermediate impedance

state such that the voltage at the connection point 9 and the load terminal 3 is higher than the voltage at the battery terminal 5.

When the battery 4 is partially charged to a battery voltage less than full charge, the telephone can be used with power supplied from the charger 6 over the path 8 while the battery is charging. The MCU 12 puts the clamp and charge control element 20 and the blocking and charge control element 21 in the intermediate, controlled impedance state or a fully conductive state, according to the power supply conditions so that the charger 6 supplies appropriate current both to the battery and to the load.

In one embodiment of the invention, when the battery 4 reaches full charge, the MCU 12 puts the clamp and charge control element 20 into its non-conductive state, so as to disconnect the charger 6 from the load 2 and the battery 4.

In another embodiment of the invention, when the battery 4 is at full charge with the charger connected, the MCU 12 puts the blocking and charge control element 21 into its non-conductive state, so as to disconnect the battery 4 from the load 2 and the charger 6, so as to leave the battery 4 in its fully charged condition during use of the telephone.

The control elements 16 and 20 are preferably FETs and preferably unidirectional FETs. However, the control element 20 may be a bidirectional FET. It is also possible for the blocking control element 16 to be a diode. The control element 21 is preferably a unidirectional FET.

The operation of this embodiment of the invention will now be described in more detail with reference to Figures 3 and 4 of the drawings. Figure 3 shows the simplified symbols used in Figure 4 to represent the different operational states of the control elements 16, 20 and 21, as shown by their equivalent circuit diagrams in Figure 3. Thus, a control element 22 in a non-conductive state is represented as a single open switch in the case of a single FET 23 or a dual open switch in the case of a dual FET 24. A control element 25 in a fully conductive state is represented as a single closed switch in the case of a single FET 26 or a dual closed switch in the case of a dual FET 27. A control element 28 in a voltage regulating state is represented by a voltage limiting symbol in the case of a single FET 29 or a voltage limiting symbol in series with a closed switch in the case of a

dual FET 30. A control element 31 in a current regulating state is represented by an arrow in the case of a single FET 32 or an arrow in series with a closed switch in the case of a dual FET 33.

Figure 4 shows the operating states of the control elements 20, 16 and 21 for the cases of no charger connected, of a low power charger connected, capable of supplying the load while charging the battery when the load is operating in conditions of low current consumption, and of a high power charger connected, capable of supplying the load while charging the battery even when the load is operating in conditions of high current consumption. The operating states are shown for the conditions of no battery connected, of a depleted ('dead') battery, of a battery in low but normal uncharged condition, of a battery close to full charge, where the charger is to supply in 'top-off conditions, and of a full battery.

When no charger 6 is connected, the MCU 12 puts both the control elements 16 and 20 non-conductive and the control element 21 either non-conductive (A) if the load 2 is not being used or conductive (B) if it is.

When a low- or high-power charger 6 is connected, the MCU 12 puts the charging clamp and charge control element 20 in the voltage clamp state and the blocking element 16 conductive. If there is no battery 4 connected (C), the MCU 12 puts the control element 21 non-conductive. If the battery 4 is connected (D), the MCU 12 puts the control element 21 in current-regulated state to conduct 'trickle' current, enabling the load 2 to operate at full voltage while still charging the battery 4, albeit slowly.

When a low-power charger 6 is connected with an at least partially charged battery 4 connected, the MCU 12 puts the control element 20 in current-regulated state, with the blocking element 16 conductive, for a normally low battery (E), the current being reduced by the control element 20 during 'top-off' when the battery 4 is close to full charge (G); in each case, the control element 21 is conductive so that the battery 4 can charge while the load 2 is operating under power supplied from the charger. When battery 4 is fully charged (I), the MCU 12 puts the control element 20 and the blocking element 16 non-conductive, the control element 21 being conductive so that the battery 4 supplies the load 2.

When a high-power charger 6 is connected with an at least partially charged battery 4 connected, the MCU 12 puts the control element 20 in current-regulated state, with the blocking element 16 conductive, for a normally low battery (F), the current being reduced by the control element 21 during 'top-off' when the battery 4 is close to full charge (H), in which case, the control element 20 is in voltage-regulation state. When battery 4 is fully charged (J), the MCU 12 puts the control element 21 non-conductive, the control element 21 being in voltage-regulation state and the blocking element 16 being conductive so that the charger 6 supplies the load 2 and preserves the charge of the battery 4.

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